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DEVELOPMENT OF AN IMPROVED HIGH EFFICIENCY THIN SILICON SOLAR CELL

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TECHNICAL CONTENT STATEMENT

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I. ABSTRACT

High Efficiency cells (up to 14% AM0 at 25°C) have been fabricated from 10 - 15 Ω-cm silicon by using screen-printed aluminum paste as the alloy source for the production of back surface fields. Thick consistency pastes that have been cured prior to a short heat treatment at 850°C were most effective in achieving these efficiency levels.

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III. SUMMARY

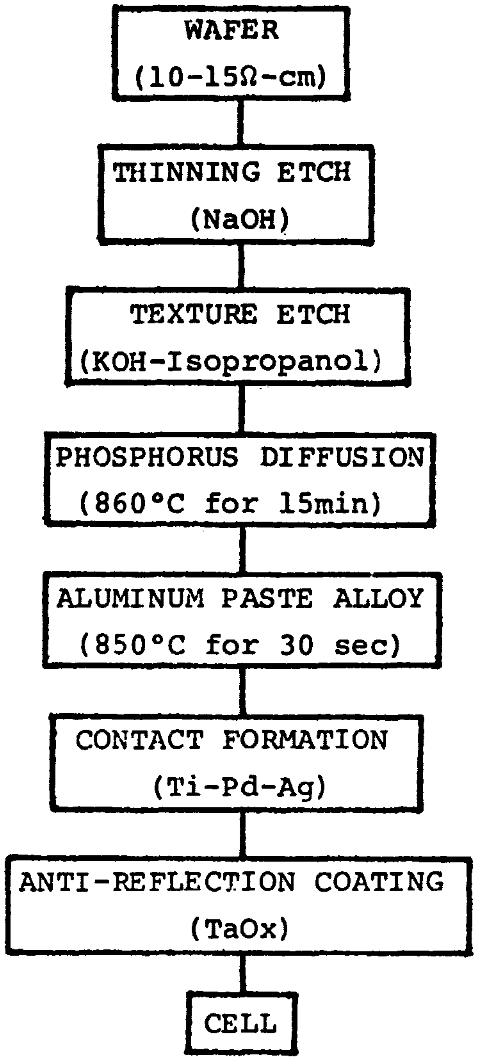
The principal goals of the work under this contract are to investigate, develop and analyze thin silicon solar cells containing back surface fields introduced by the alloying of screen-printed aluminum pastes. During the quarter, the effects of paste composition and paste heat treatments were investigated. This effort has resulted in 4 cm^2 cells of 50 - 75 μm thickness and 10 - 15 Ω-cm resistivity having a maximum AM0 efficiency of ~ 14.0% (P_{max} = 77 mW at 25°C). Open circuit voltages above 590 mV and as high as 600 mV were measured. It was found that thicker consistency pastes coupled with curing the pastes prior to alloying gave the best results.

IV. TECHNICAL DISCUSSION

1. During the past quarter, major efforts have been directed towards achieving high V_{oc}, high efficiency thin cells using aluminum pastes as the source for back surface fields. Textured silicon wafers having a base resistivity of 10 - 15 ohm-cm and a thickness of 50 - 75 μm were used to fabricate cells. The processing sequence is that shown in Figure 1.

The first experiment was directed towards determining the influence of paste consistency on the V_{oc}.

Figure 1: Process Sequence



Englehard paste #A-3484 of two consistencies was screen onto the textured backs of diffused wafers. One consistency was that as obtained from Englehard and the other was that which resulted by adding on equal amount of thinner. The pastes were not given a cure prior to being inserted into a furnace at 850°C. Flaming of the organic binder occurred, and the wafers were removed after ~ 30 seconds. The results are seen in Table I. They show very clearly that the thicker consistency paste gives higher open circuit voltages.

The next experiment was directed towards determining the effects of curing the paste at a low temperature prior to alloying. One group of cells was alloyed with no prior curing and another group was cured at 90°C for 10 minutes before alloying at 850°C for 30 seconds. The results of this experiment are seen in Table II. Again, the results clearly show that the pre-curing gives higher V_{oc}'s.

Then, another group of cells was processed using the pre-cured paste in order to determine whether the previous results were reproducible. The results are seen in Table III. Consistently high V_{oc}'s and maximum powers were obtained. The best cell has an AM0 power output of 77 mW at 25°C (Figure 2), comparable to the best results obtain previously on 2 ohm-cm Si having evaporated Al as the alloy source.

TABLE I

Open circuit voltages of cells whose back surface fields were formed from different consistency aluminum pastes.

1. Thick consistency paste (no dilution)

V_{oc} (5 cells)	=	561 mV
V_{oc}^{min}	=	549 mV
V_{oc}^{max}	=	570 mV

2. Thin consistency paste (1 part paste, 1 part thinner)

V_{oc} (12 cells)	=	508 mV
V_{oc}^{min}	=	503 mV
V_{oc}^{max}	=	512 mV

TABLE II

Open circuit voltages of cells whose back surface fields were formed with different alloying procedures.

1. Alloying of cured paste

$$V_{oc}\ (30\ \text{cells}) = 582\ \text{mV}$$
$$V_{oc}^{min} = 556\ \text{mV}$$
$$V_{oc}^{max} = 595\ \text{mV}$$

2. Alloying of wet paste

$$V_{oc}\ (17\ \text{cells}) = 566\ \text{mV}$$
$$V_{oc}^{min} = 551\ \text{mV}$$
$$V_{oc}^{max} = 577\ \text{mV}$$

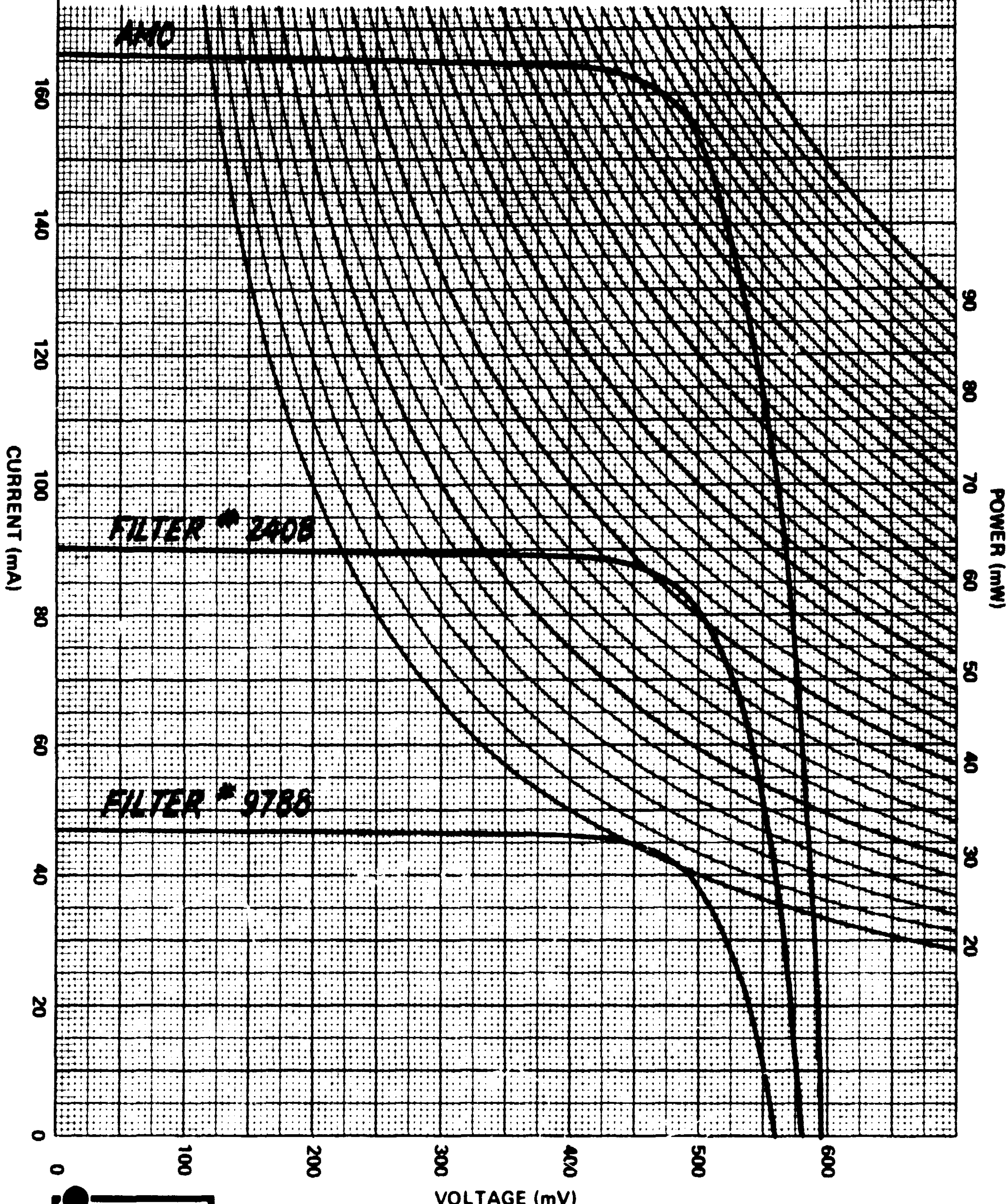
TABLE III

Output characteristics obtained from thin, textured cells using thick consistency, cured aluminum pastes as the back surface field source.

Cell #	I_{sc}	I_{sc}blue	I_{sc}red	V_{oc} 25°C	P_{max}
1	156	47	83	593	73
2	156	46	84	593	72
3	162	47	87	596	75
4	161	47	86	593	74
5	166	49	89	599	76
6	165	49	88	597	75
7	163	47	87	592	75
8	164	48	88	599	75
9	164	49	87	600	76
10	166	48	90	597	77
11	161	48	85	595	75
12	162	48	86	596	75
13	161	47	86	589	73
14	164	48	88	579	74
15	163	48	87	595	76
16	165	48	89	598	76
17	164	48	88	592	75
18	163	48	87	583	74
19	162	48	86	596	75
20	166	47	90	596	75

Note: Simulator calibrated with respect to an airplane flown 50μm textured cell.

Figure 2. AM0, Red and Blue I-V curves at 25°C for highest efficiency thin cell fabricated using aluminum paste as a source for the back-surface field.



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FORM 11142

Cell Type TEXTURED 2x2 No. LOI 2854 By TT Date /

Future experiments will be concerned with investigating the effects of alloy time and temperature on the V_{oc} and maximum power. The goal is to produce V_{oc}'s consistently greater than 600 mV and P_{max}'s greater than 74 mW on 10 Ω-cm silicon.

2. Sixteen 50 μm thick cells having a base resistivity of 10 - 15 ohm-cm and a back surface field produced from an evaporated aluminum source were fabricated and delivered to JPL. The front surface was smooth, and the back surface was textured. The output of these cells are shown in Table IV. Power levels equivalent to those obtained from 2 ohm-cm silicon were achieved.

V. CONCLUSIONS

1. AM0 efficiencies exceeding 14% can be obtained from textured 50 - 75 μm cells fabricated from 10 - 15 Ω-cm silicon.

2. Thick consistency pastes that are cured prior to a short alloy program at 850°C result in high open-circuit voltages and efficiencies.

TABLE IV

Output characteristics of 50μm thin cells fabricated from silicon wafers of the specified resistivity. Source of back surface fields was evaporated aluminum.

Cell No.	I_{sc} mA	I_{sc}blue mA	I_{sc}red mA	V_{oc}25°C mV	P_m mW	ρ Ω-cm
1	148	40	81	553	61	25
2	149	41	81	551	62	14
3	147	42	79	557	61	15
4	149	40	82	557	62	15
5	149	41	82	567	65	15
6	149	41	81	566	63	17
7	149	43	80	547	60	15
8	147	40	81	550	61	15
9	148	42	81	565	64	17
10	147	43	77	552	60	15
11	149	41	81	561	63	15
12	148	42	80	562	62	16
13	148	42	79	562	62	16
14	143	42	76	574	63	19
15	148	41	81	567	64	17
16	147	40	84	561	62	13